Miami and West Palm Beach hurricanes. In Key West, there are a considerable number of frame buildings that have withstood all the hurricanes of the last 50 years at that place without serious damage. One frame structure on the Government reservation has safely passed through all the Key West hurricanes since 1846.

Observations of the storm areas of the severe hurricanes on the east coast of Florida in 1926, 1928, and 1929 warrant the following statement.

If a building is properly constructed, including the proper type of roof and roofing material, and is securely anchored to the proper kind of foundation, it will not sustain serious structural damage in a hurricane of major intensity. If, in addition to the proper construction, all windows, doors, and vents are protected by storm shutters, the building should withstand strong hurricane winds with practically no damage. Such a building can be constructed at only a moderate increase of cost above that for the usual type of construction, and the saving in storm insurance will repay the extra cost in a few years time.

Grateful acknowledgment is made to Mr. B. K. Durst, who prepared two of the tables used in this paper.

LITERATURE CITED

(1) Mitchell, Charles L., Hurricanes of South Atlantic and Gulf States.
(2) Mitchell, Charles L., West Indian Hurricanes and other Tropical Cyclones of the North Atlantic Ocean: W. B. No. 840:39.
(3) Gray, Richard W., Monthly Weather Review, 47:639.
(4) Mitchell, Charles L., Monthly Weather Review, 57:419.
(5) Kadel, Benjamin C., Monthly Weather Review, 54:414.

(NOTE.—No tropical storms of consequence passed over Florida during 1931 or 1932.—Editor).

LAKE OKEECHOBEE AND SAFETY FROM TROPICAL STORMS

By A. J. MITCHELL

[Weather Bureau Office, Jacksonville, Fla.]

SYNOPSIS

This paper describes Lake Okeechobee as to area, depth, configuration, drainage area, and other features, particularly with reference to the hurricane disasters of 1926 and 1928.

Lake Okeechobee is in the south-central portion of the Florida peninsula; it is between 30 and 40 miles in diameter. The surface of the lake is between 700 and 800 square miles; its depth varies from a maximum of 15 feet to only a few inches at the outer circumference, especially on the south and west shores where the water is shallow. The configuration of the lake is nearly round, and its drainage area comprises 5,300 square miles. The Everglades, an area about 90 miles long and 40 miles wide, compose an area of 4,500 square miles; they are just to the south of the lake and over which shore (south) the flood waters of Lake Okeechobee found their exit to a large extent. It was to drain these glades that inspired the first efforts of Gov. N. B. Broward in seeking a platform in race for governor. Broward made the race on "Draining the Everglades," which platform carried him into the State's executive chair, and later to the very door of the United States Senate, but a cruel fate decreed that he should not enter; he died before he took his seat.

I have, thus, termed the Lake Okeechobee and Everglades project: An industrial baby, born of a political exigency.

Progress now being made to offset the dreadful incidents which have attended tropical storms in the Okeechobee region during the last few years should prove reassuring to many who have property and other interests in the Everglades district. The State of Florida and the Federal Government are constructing levees on and around the lake to the end that disasters such as those that attended the hurricanes of 1926 and 1928 shall not recur.

There has been so much apprehension in some circles regarding the safety of life and property on Lake Okeechobee, Fla., since the occurrence of the hurricanes of 1926 and 1928 that it seems wise to give publicity to the activities of the Federal Government and the State of Florida on the lake with the assurance that when the projects now under way shall be fait accompli there need be little concern with respect to the security of all interests on Lake Okeechobee and adjacent waters, regardless of the possible severity of tropical disturbances which, however, are by no means of annual occurrence.

Lake Okeechobee is between 30 and 40 miles in diameter, being the largest body of fresh water within the continental interior of the United States, exclusive of Lake Michigan which we do not consider as coming within the purview of this paper.

Geographically, the lake is in the south-central portion of the Florida peninsula. It is generally round, suggestive of a natural amphitheater, the depth varying from a maximum of about 15 feet to a gentle wind tide of a few inches near the outer rim of the lake, especially on the south and west shores. Latitude 26″ north and longitude 81° west bisect, so to speak, the center of the lake.

The geological history of the State indicates that Lake Okeechobee was much larger at one time, and that it fills an original depression in the floor of the sea which once covered the coastal terrace. Pleistocene and pliocene shells are seen on the spoils banks of the canals, and the shoal waters out from Moore Haven are underlain with pleistocene shells, marl, and limestone; thus giving some knowledge of the varying life phases of the peninsula, which appears to be quite ancient.

The water surface of Lake Okeechobee is between 700 and 800 square miles, and it has a drainage area, mostly to the north, comprising 5,300 square miles which represent in the aggregate the drainage areas of Taylors Creek, Fisheating Creek, and the Kissimmee River, the last named being the chief tributary, reaching to the northward 137 miles as measured by the course of the stream, but in reality less than 100 miles. The deepest water in the lake will not be more than 15 feet when the elevation of the water surface of the lake is 15 feet above mean low water at Punta Rassa on the Gulf of Mexico.

Immediately to the south of Lake Okeechobee are the Everglades, a low marshy area about 90 miles long and 40 miles wide, comprising 4,500 square miles. These lands slope toward the southern end of the Florida peninsula at the rate of 2 or 3 inches to the mile. Originally, the elevation of the Everglades bordering on the lake was 21 to 22 feet above mean low water of the Gulf of Mexico, but as a result of drainage operations the land has subsided to 17 and 19 feet above the mean low water of the Gulf. A large volume of the flood waters of the lake is or was discharged over its southern rim, and before the drainage work became effective the Everglades were covered by several feet of water. As evidence of the vagaries of lake stages its depth varying with the volume supplied by its tributaries, the deficiency in rainfall during the year 1931 has resulted in a decided contraction of the water line, and at this time one can walk dry shod about one mile nearer the lake's center; in fact, enterprising truck growers have

planted crops on land which was, normally, a part of the lake bottom.

The dwellers on Lake Okeechobee may have been cognizant of the fact that high water was possible under a concert of conditions, but the possibility of a disaster on this erstwhile tranquil lake had never been suggested.

Metaphorically, the hurricane is the monarch of the air; like a thing of life it marches with measured tread over land and sea; it grants no favors, but it exacts enormous tribute.

It was this knowledge and the coincidental occurrence of high water on Lake Okeechobee and the Miami hurricane of 1926 with the sequence of a major tragedy at Moore Haven and Miami, which brought to the attention of all concerned the necessity for greater protection to life and property against the almost irrestible powers of wind and water. It will be needless repetition to treat in extenso the hurricanes of September, 1926 and 1928, as the important meteorological data are known of all men, especially Weather Bureau men.

STORM OF SEPTEMBER, 1926

The hurricane of September, 1926, approached the coast at Miami about 6:45 a. m. of the 18th, continuing northwestward to the south of Fort Myers, Fla., and across the Gulf to the south of Mobile; thence to the Mississippi coast, dissipating over Louisiana. The lowest barometer reading at Miami was 27.61 inches, as shown by the photostatic copy on the lower left of the chart; it was the lowest reading of record in this country, and it was close to the world record, 27.02 inches, during a typhoon in China, August, 1891. Hann is my authority for the latter value. As shown by the chart, the center of the storm was to the south of the lake, as hurricane winds from the northeast continued until the afternoon, breaking and topping the levees in the vicinity of Moore Haven and piling up water to an elevation of 29 feet, with resulting deaths and property loss in that district.

The water surface of Lake Okeechobee on August 26, 1926, was 18 feet above mean low water of the Gulf, and just before the hurricane of September 17–18 the surface of the lake was at elevation 19.2 feet, and for some time after the hurricane the elevation was 19.8 feet, the rise from 19.2 to 19.8 being due, no doubt, to the heavy rains during the storm among which the following, inches and tenths, are mentioned: Bradenton, 8.8; Fort Myers, 8.0; Hypoluxo, 5.6; Belle Glade, 4.3; Jupiter, 5.7; St. Petersburg, 6.5; Pinellas Park, 6.6; and Miami, 8.0, incomplete. The following amounts fell during the 19–20th over the northern and northwestern counties, as the center moved across the Gulf: Apalachicola, 4.5; St. Andrew, 7.7; Quincy, 6.2; Mount Pleasant, 6.5; Vernon, 6.5; Marianna, 6.3; Bonifay, 6.8; Pensacola, 8.6; Bluff Springs, 11.2; and Blountstown, 16.4 inches.

STORM OF SEPTEMBER, 1928

The center of this storm passed over Palm Beach about 7:30 p. m. of September 16, thence to the south-central portion of the peninsula, the center bearing somewhat to the east and north, although the lake was well under the influence of the center, as the usual calm obtained. Hurricane winds prevailed from the north-northwest, becoming south-southwest as the center passed. The north-northwest winds piled up water, a severe storm wave, to an elevation of 29 feet in the pocket of the southern rim of the lake, which spelled the doom of 1,700 souls. The wind shift to the south-southwest, incident to the passing of the center, reversed the direction of the storm wave from the southern shores to the northern pocket of Taylors Creek where others were overwhelmed on those unhappy waters. The lowest barometer reading at Palm Beach was 27.45 inches, which was appreciably lower than during the Miami storm of 1926. The center of this storm moved to the northward within the peninsula, passing Jacksonville slightly to the westward during the early hours of September 18. The lowest barometer readings are shown on the photostatic copy attached to the chart on the lower right.

It was the high water together with the severe wave action that washed away much of the levees in the vicinity of Moore Haven during the storm of 1926, the same having been provided to protect, rather to prevent the lake overflow onto the Everglades; the levees were not constructed with the viewpoint of life protection, as the same, probably, had never received consideration from any source. This, however, is no criticism of those who directed activities on the lake, as their ability was unquestioned and their vision as to the occurrence of untoward events was as reliable as were the teachings of history relating to Lake Okeechobee and associated waters.

The storm tides were increased, no doubt, during both storms owing to the shallow water some distance from the shores on the south and west sides of the lake which greatly retarded the return of the subsurface flow. The bottom of the lake on the east shore slopes at a much steeper angle, thereby facilitating the subsurface flow which, probably, explains its freedom from the melancholy history of the lake, as written by the storms of 1926 and 1928.

A clear understanding of the objects to be accomplished by the State of Florida, as compared with the objective of the Federal Government in their respective activities on Lake Okeechobee, will prove reassuring.

The organic law of the State of Florida having to do with initiating work in the Everglades was to provide drainage, irrigation, and flood control of the lake; several million acres of land were to be reclaimed for agriculture and horticulture, expenditures along that line up to the present amounting to about $20,000,000.

In contrast with the State's mandate, the high purpose of the Federal Government is, primarily, to safeguard life and property, and, incidentally, improve commerce by the widening and deepening of channels, rivers, lakes, and canals.

At the time of the hurricane of September, 1926, the five canals, namely, the West Palm Beach, Hillsboro, North New River, Miami, and the St. Lucie had been completed, except that the St. Lucie Canal, which is the chief outlet for the lake, was not functioning to its capacity, which was 2,500 cubic feet per second. The State's drainage board decided that the discharge of the St. Lucie Canal should be doubled to regulate more effectively the lake stages. In that connection, however, the United States engineers in their report of April 2, 1928, on survey of Calloosahatchee River and Lake Okeechobee drainage, fail to concur with the State's drainage board as to their conclusions regarding amplified work to care for abnormal floods, or storm conditions on Lake Okeechobee. The United States engineers made the following report:

It should be clearly understood that neither the recommended increased capacities of outlet canals for the control of Lake Okeechobee nor further increase in outlet capacities within the bounds of reasonable expenditures would be sufficient to hold the water surface of Lake Okeechobee at the same level at all times. In other words, during the rainy season water accumulates in Lake Okeechobee very much faster than it can be taken out by any practical method.

With that definite declaration by the Federal engineers with respect to regulating the stages of Lake Okeechobee the river and harbor act, approved July 3, 1930,

Provided for the flood control of Lake Okeechobee and certain navigable channels leading from the lake to tide water on either side of the peninsula.

The comprehensive character of the project, now being aggressively advanced, is such as to dispel fear and restore confidence in the security of life and property on Lake Okeechobee, all vouchsafed by the integrity of the Federal Government. Both outlets of the lake, namely, the St. Lucie Canal and the Caloosahatchee River, become links in the chain of intracoastal waterways of the United States.

The magnitude of the project is apparent when it is stated that levees, dykes, locks, and other control measures will form a sort of arc of a circle, extending from Fisheating Creek on the southwest shore via Moore Haven, Clewiston, Belle Glade, Pahoka, and Port Mayaca (St. Lucie Canal) on the south, a distance of 63 miles. The standard design of the protection levees provides for a crest elevation of 34 feet above mean low water of the Gulf at Punta Rassa with a crest width of 15 feet, a most formidable and enduring arm of safety.

And as a supplementary agency to regulate the lake stage, the discharge output of the St. Lucie Canal, which is now 5,000 cubic feet per second, is available should any emergency arise.

To combat all danger of floods over the northern shore of the lake, that is the Taylors Creek section, a system of levees similar to that provided for the southern shores will be constructed along the shore from the mouth of the Kissimmee River to and past Taylors Creek, a distance of 24 miles with levees on each side of the creek leading up to Okeechobee City. And there is or will be further safety through the discharge of 2,500 cubic feet per second through the Caloosahatchee Canal from Lake Okeechobee to Fort Thompson, a distance of 23 miles.

The following are coordinate parts of the Lake Okeechobee project:

(*a*) Provide a channel 200 feet wide and 12 feet deep from the Gulf to Punta Rassa.

(*b*) A channel 100 feet wide and 10 feet deep from Punta Rosa to Fort Myers.

(*c*) A channel 80 feet wide and 6 feet deep, Fort Myers to Lake Okeechobee, thence through the lake a channel 6 feet deep and 80 feet wide to the St. Lucie Canal. This canal has a minimum depth of 8 feet and a bottom width of from 150 feet to 165 feet.

The completion of the Lake Okeechobee system in its entirety sustains a relationship to the intracoastal waterways of the United States that is much more than simply a chain or link in that system which, it is conceded, might become an important factor in the communication system of the country during periods of national stress. Then Lake Okeechobee and its associated waterways would become an avenue of ingress and egress for the Gulf of Mexico and the Atlantic Ocean, really an arm of offense and defense of the Navy, making possible a rapid shift from the Gulf to the Atlantic of such forces as might be necessary to meet unexpected attacks, or to make possible a quick offense by the smaller units of the United States Navy.

THE RELATIVE DISTRIBUTION OF EARLY AND LATE SEASONAL RAINFALL IN SOUTHERN CALIFORNIA

By CHARLES C. CONROY

In view of popular and journalistic speculation as to the probability of late rains when early ones have been abundant, and because of the widespread interest in the subject of seasonal precipitation in Southern California, the writer has undertaken to analyze the relative distribution of early and late rainfall in that region. The analysis covers the period from July 1, 1877, to June 30, 1927—50 seasons—and is based upon the records, grouped by decades, of the two regular weather bureau stations—Los Angeles and San Diego. The results are tabulated below. In the tables, column (*a*) shows the total rainfall by decades and for the period; column (*b*) the corresponding early rainfall; column (*c*) its percentage of the decadal and total rainfall; column (*d*) the corresponding late rainfall; column (*e*) its percentage of the decadal and total fall for the period, and column (*f*) the percentage of the total fall represented by the midseasonal rains. The word "early" is used to designate the five months from July 1 to December 1; the word "late" the three months from April 1 to July 1. The expression "midseasonal" comprises the months of December, January, February, and March. In the "early" part of the rain year July and August have contributed only an inappreciable amount to the totals, so the early period is really strictly comparable, in length, with the "late" months of April, May, and June.

Los Angeles

	(*a*)	(*b*)	(*c*)	(*d*)	(*e*)	(*f*)
	Inches	*Inches*	*Per cent*	*Inches*	*Per cent*	*Per cent*
1877-87	172.34	19.88	11.5	27.35	15.8	72.7
1887-97	167.69	25.51	15.2	7.08	4.2	80.6
1897-07	132.96	22.47	16.1	15.34	11.5	72.4
1907-17	160.31	17.54	10.9	7.65	4.8	84.3
1917-27	127.79	17.67	13.8	21.26	16.7	69.5
Sums	761.39	103.07		78.68		
Means	152.28	20.61	13.5	15.74	10.6	75.9

San Diego

1877-87	122.35	13.07	10.7	17.45	17.4	71.9
1887-97	99.15	13.94	14.1	5.26	5.3	80.6
1897-07	88.60	12.98	14.6	12.42	12.4	73.0
1907-17	106.20	16.55	15.6	7.33	7.3	77.1
1917-27	99.65	15.19	15.2	14.34	14.4	70.4
Sums	515.95	71.73		56.80		
Means	103.19	14.35	14.0	11.34	11.4	74.6

The outstanding features of the two tables are (1) the comparative constancy of the early (*c*) and mid-seasonal (*f*) rainfall as expressed in percentages of the whole; and (2) the wide variability and consequent uncertainty of the late rainfall, both in actual amounts (*d*) and in percentages, (*e*). In both Los Angeles and San Diego the departures from the mean are far larger in the late rain-